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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 183.

B. T. GALLOWAY, *Chief of Bureau.*

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FIELD STUDIES OF THE CROWN-GALL OF THE GRAPE.

BY

GEORGE G. HEDGCOCK,
PATHOLOGIST, FRUIT-DISEASE INVESTIGATIONS.

ISSUED JULY 23, 1910.

WASHINGTON:
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1910.

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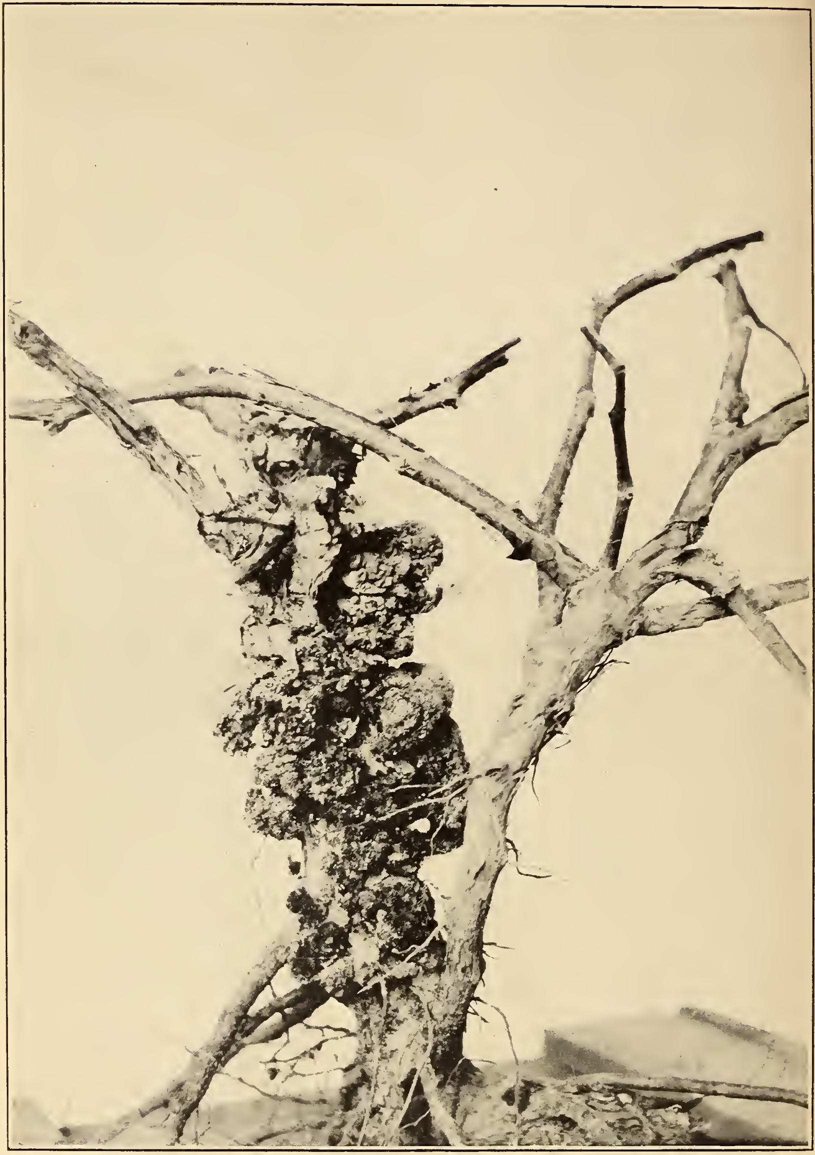

A MISSION GRAPEVINE BADLY DISEASED WITH CROWN-GALL, SHOWING AN OLD DEAD CANE AND A YOUNG LIVE ONE FROM THE ROOT.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 11, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Field Studies of the Crown-Gall of the Grape," by Dr. George Grant Hedgcock, Pathologist, Investigations in Forest Pathology.

The paper embodies the results of several years of investigation of the crown-gall of the grape in the western United States, especially of the susceptibility and immunity to the disease of a number of the most important varieties of grapes. It is found that a few varieties are resistant to the crown-gall, and that the use of the varieties Rupestris St. George and Lenoir as stocks for engrafting congenial nonresistant varieties affords a ready means of successfully overcoming the effects of the disease under soil and climatic conditions favorable to such varieties.

Studies on the congeniality of *Vitis vinifera* to resistant stock varieties, and the adaptation of varieties to soil, climatic, and other conditions, are discussed by Prof. George C. Husmann in Bulletin 172 of this Bureau.

The writer of this paper is indebted to Prof. Fabian Garcia, of the Agricultural Experiment Station of New Mexico, for hearty cooperation in obtaining information as to the extent of crown-gall in that Territory.

This paper completes the work of Doctor Hedgcock on the subject, but studies of the field end of this disease will be continued by the Office of Fruit-Disease Investigations of this Bureau.

I recommend that this paper be published as Bulletin No. 183 of the special series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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FIELD STUDIES OF THE CROWN-GALL OF THE GRAPE.

INTRODUCTION.

A disease of grapevines, under the various names of "black-knot," "crown-knot," "root-knot," "crown-gall," and "root tumors," has been known in the United States for many years. As early as 1880 it had become common in California (61)[a] and often resulted in serious injury to the vineyards. With the introduction of European vines into new localities the disease has become widespread.

During 1903 Prof. Fabian Garcia, of the New Mexico Agricultural Experiment Station, found that a disease was killing the grapevines at Bernalillo, N. Mex. The station having no plant pathologist the Bureau of Plant Industry was requested to make an investigation of the epidemic, and the task was assigned to the writer.

A preliminary examination of the vines revealed the presence of galls in large numbers on the canes and roots of many of them. Experiments were at once undertaken for the control of the disease and the cure of the diseased vines. After a thorough test of ordinary remedies with little or no results, an experiment was conducted to find varieties resistant to the disease.

Meanwhile studies were made of the cause, nature, communicability, and effect of the disease. This involved a number of species and varieties of grapes and a series of experiments in the greenhouse and gardens at St. Louis, Mo., and later at Washington, D. C.

This bulletin outlines the history of the disease and gives the results of these studies and experiments, which are of a preliminary nature, but are of great importance, especially to growers of grapes in Texas, New Mexico, Arizona, and California. Certain varieties of grapes are found to be so susceptible to crown-gall as to be unprofitable for vineyards in many localities, while others are resistant to a considerable degree and are recommended for planting. Methods for the prevention and control of the disease are outlined.

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[a] The serial numbers in parentheses used in this paper refer to the bibliography which will be found on pages 31 to 33.

Prior to July 1, 1907, this investigation was conducted in the Mississippi Valley Laboratory of the Bureau of Plant Industry at St. Louis, Mo., under the supervision of Dr. Hermann von Schrenk.

For convenience, two forms of crown-gall of the grape are recognized in this bulletin. The underground or subterranean form developing at or below the surface of the ground (see Pl. III) is designated as root galls; the form appearing on the canes of the vines above the surface of the ground (see Pl. II, fig. 2) is designated as cane galls.

HISTORICAL NOTES.

It is probable that the crown-gall of the grape originated in the older countries of Europe or possibly in Asia where vines were first cultivated, but efforts to trace the disease even back to the middle ages were futile.

The first written record found in the literature examined was a reference to the form of the disease occurring on the canes of the grapevine by Fabre and Dunal (19) in 1853. This form is usually called "broussin" or "broussins" in French descriptions. According to Viala (55) it is also called, including the form on the roots, "exostoses," "exostoses fungoides," and "fongosités." The following French investigators have described and reported the disease: Cazalis (6) and Joly (32) in 1873; Du Breuil (16) in 1875; Planchon (38) and Seillan (42) in 1882; Corvo (11) in 1885; Prillieux (39) in 1888; Viala in 1887 (55), 1893 (57), and 1896 (56); Zacharewicz (63) in 1894; Ravaz (40) and Giard (25) in 1897; and Durand (18) in 1907.

In Germany, Dornfield (15) in 1859 described a form of disease called "Grind," consisting of galls or outgrowths on the canes of grapevines. This form of disease has also been known in Germany by the names "Schorf," "Raude," "Mauche," "Ausschlag," "Krebs," and "Kropf," the last name being also applied to the form of the disease appearing as galls upon the roots of vines.

Since Dornfield's time the following investigators in Germany have written concerning the disease: Köhler (33) in 1869; Goethe in 1875 (28), 1878 (26, 27), and 1882 (29); Von Thümen (58) in 1884; Beinling (2) in 1891; Frank (21) in 1895; and Sorauer in 1886 (48) and 1908 (46, 47).

In Italy, Garovaglio and Cattaneo (23) in 1879 described a disease called "rogna" on the canes and roots of the grapevine similar to the disease known in France as "broussins" and in Germany as "Grind." This was followed by publications by the following investigators: Comes in 1885 (8) and 1891 (7); Corvo (11) in 1885; Cuboni (12) in 1889; Martelli (37) in 1891; and Cavara in 1895 (4) and 1897 (5). The disease is also known in Italy under the names "malattia dei tubercoli" and "tubercoli."

In the United States in 1889 Galloway (22) under the name of "black-knot" described the form of crown-gall occurring on the canes of grapevines. This he considered the same as the "broussins" of the French, the "Krebs" or "Schorf" of the Germans, and the "malattia dei tubercoli" of the Italians. The disease on the canes or roots of grapevines has since either been reported or described in the United States by the following investigators: E. F. Smith (44) in 1894; Woodworth and Wickson in 1892 (61) and 1894 (62); Stewart and Blodgett (49) in 1899; Stewart, Rolfs, and Hall (50), and Toumey (51) in 1900; Garcia (24), Whipple (59), and Hedgcock (31) in 1906; and Lawrence (35) in 1907. Under the name "necrosis," Reddick (41) in 1909 described a gall disease of the canes of grapevines in New York which is apparently the same as the crown-gall, "broussins," "rogna," and "Grind."

In England, Cooke in 1893 (9) and 1903 (10) described a gall on the roots of grapevines which resembles the crown-gall in its gross appearance.

In Canada, Fletcher (20) in 1889 described a disease of the canes of the grapevine under the name "black-knot," which is apparently the same as the form described by Galloway (22) and Reddick (41) and the crown-gall occurring on the canes of vines of European grapes (*Vitis vinifera* L.) described in this bulletin.

In Chile, Dehors (13) in 1894 and Lataste (34) in 1896 described a tubercular or gall disease of the grape similar to the crown-gall of the roots of vines in this country.

In New South Wales, Blunno (3) in 1901 reported a cancerous disease of the grapevines which is apparently the same as the forms of the disease on the canes and roots of vines in this country and Europe.

In Cape Colony the disease is reported by letter by the entomologist, C. P. Lounsbury, with specimens on the canes of grapevines undoubtedly identical with the form of disease described on the canes of vines in this bulletin.

In the Netherlands, Van Hall (54) in 1902 described a gall disease of the grapevines, which he considered the same as the "rogna" of the Italians.

The disease has been observed by the author on the canes of grapevines in northern Mexico near Ciudad Juarez and Nogales.

DISTRIBUTION AND IMPORTANCE OF CROWN-GALL.

GEOGRAPHICAL DISTRIBUTION OF THE DISEASE.

If all the forms reported by the citations on the preceding pages are one disease, which is very probable, the crown-gall is widely distributed and probably occurs wherever European grapes are grown.

The crown-gall or a similar disease is thus reported on grapevines in Europe from Germany, France, Italy, Denmark, and England; in North America, from the United States, Canada, and Mexico; in Australia, from New South Wales; and in Africa, from Cape Colony.

In the United States the disease occurs in nearly every locality where varieties of *Vitis vinifera* are grown. It occurs on some American varieties in Canada and various portions of the United States. The author has observed the disease in localities in the following States and Territories: Washington, Oregon, California, Arizona, New Mexico, Colorado, Texas, Arkansas, Nebraska, Missouri, and Iowa.

DISTRIBUTION OF THE DISEASE ON SPECIES AND VARIETIES OF GRAPES.

In the United States, as well as in foreign countries, the varieties most susceptible to the disease belong to the species *Vitis vinifera.* There are a few exceptions to this rule, especially in the northern United States (41) and Canada (20), where varieties, hybrids or crosses, of *Vitis labrusca,* Champion, Salem, and others are attacked by the form of the disease on the canes. Varieties of *Vitis linsecomii* and *Vitis aestivalis* are occasionally diseased on both canes and roots. Varieties of *Vitis rupestris* are rarely attacked by either of the forms of the disease and appear to be nearly immune. Data will be given later in this bulletin on the resistance of individual varieties of several species.

DISTRIBUTION OF THE DISEASE ON YOUNG AND OLD VINES.

The disease has been found to a limited extent on the roots of yearling vines of *Vitis vinifera* in vineyards and nurseries in Texas, Arizona, New Mexico, California, Oregon, and Washington. It is most common on the roots and canes of older vines, increasing in extent as the vines grow older. The oldest vineyards usually contain the highest percentage of diseased vines.

IMPORTANCE OF THE DISEASE.

In Germany, France, and Italy earlier writers report whole vineyards destroyed by the crown-gall. Later writers minimize the importance of the disease. This decrease of disease is no doubt due largely to the use of American varieties of grapes and their hybrids for ingrafting with varieties of *Vitis vinifera* in the replanting of vineyards destroyed by the phylloxera. It may also be due to the gradual selection of the more resistant European varieties by growers of grapes. Our observations and experiments sustain such a conclusion, since American varieties are more resistant to the crown-gall and a great variation of susceptibility is shown by European varieties.

In Cape Colony, as well as in the United States, certain varieties are subject to the crown-gall, such as the Muscat of Alexandria (Hanepoot). Mr. C. P. Lounsbury reports, by letter, that as much as 70 per cent was found diseased in a vineyard six or seven years old planted with Hanepoot (Muscat of Alexandria) vines. In vineyards in Texas, New Mexico, and Arizona all the vines of this variety and of the Mission variety are often diseased, and many of them are dead at the end of four years. In one vineyard at Bernalillo, N. Mex., 3,000 Mission vines died from the disease in four years from the time the vineyard was planted. The loss from the ravages of the disease is a large and important item in many localities, especially in this section, amounting to many thousands of vines.

If we consider the northern form of disease known as necrosis (41) or black-knot (22) as identical with crown-gall, the importance of the disease is greatly increased. Until it has been definitely proved that this form of disease is due to a different organism, owing to the apparent similarity of the black-knot of the Northern States and the cane-gall form of crown-gall in the Southwestern States, the writer will consider these forms of disease identical.

DESCRIPTION OF THE FORMS OF CROWN-GALL.

ROOT GALLS.

The disease is most frequently found in its earlier stages in the form of more or less spherical, fleshy galls, or outgrowths (Pl. III, fig. 2), from the roots of young plants grown from cuttings or at the point of union of scion and root in young grafted vines. These usually originate in a wound. They often become confluent (Pl. II, fig. 1).

These galls at first are white or flesh colored and can not be distinguished from callus, but they usually develop more rapidly. The surface as they grow older is more or less coarsely convoluted. They more frequently occur near the surface of the ground and often attain a diameter of 2 or 3 inches on large vines.

CANE GALLS.

The disease on old vines extends from the crown upward and attacks the older branches of the canes, often to the height of from 3 to 5 feet from the ground. Fleshy excrescences or confluent galls develop usually along lines parallel to the length of the canes (Pl. II, fig. 2). These growths are sometimes continuous for several inches or may develop in bunches. In spring the young galls resemble wound tissue, but later in the season they often assume a dark-brown or black color due to the death and decay of the outer tissues.

OTHER MANIFESTATIONS OF THE DISEASE.

The disease manifests itself in a number of ways in addition to the formation of galls. The affected vines are stunted in their growth. The leaves are usually smaller and are often etiolated or chlorotic. The galls usually die annually, and if under ground they commonly rot away, the decay killing the adjacent tissues of the root and often killing the vine above the point of attack.

DEVELOPMENT OF THE FORMS OF CROWN-GALL.

DEVELOPMENT OF ROOT GALLS.

The subterranean form of the disease usually does not develop abundantly the first year on vines grown from cuttings. An exception must be made where cuttings are taken from diseased vines. In an experiment with cuttings selected from healthy and diseased vines of the same varieties a marked difference was noted in the relative development of the disease. The experiment was conducted as follows:

Cuttings were taken from apparently healthy and from plainly diseased Thompson Seedless, Zabalkanski, Black Malvoisie, and Mission vines from the same vineyards at Bernalillo and Mesilla Park, N. Mex. They were planted in the greenhouse in sterilized soil in sterilized pots[a] and watered with boiled water. The results of the experiment are shown in Table I.

TABLE I.—*Results of an experiment to determine the relative susceptibility to crown-gall of four varieties of grapes grown in New Mexico, cuttings being made from apparently healthy vines and from vines plainly diseased.*

Variety.	Diseased cuttings.			Healthy cuttings.		
	Number of plants in test.	Healthy plants resulting.	Diseased plants resulting.	Number of plants in test.	Healthy plants resulting.	Diseased plants resulting.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Thompson Seedless	25	80.0	20.0	33	100.0	0.0
Zabalkanski	4	50.0	50.0	7	100.0	.0
Black Malvoisie	43	60.5	39.5	43	79.0	21.0
Mission	19	68.4	31.6	19	94.7	5.3
	91	67.0	33.0	102	90.2	9.8

It will be seen from the table that the use of cuttings taken from plainly diseased plants increased the development of the crown-gall from 9.8 to 33 per cent, or 23.2 per cent. It is also seen that where cuttings were selected from apparently healthy vines in diseased vineyards some of them (9.8 per cent) became diseased upon rooting. Similar results were obtained by cuttings planted in the soil in a vineyard.

---

[a] Sterilized in an autoclave for three hours at a temperature of 110° C. (230° F.).

Nearly all of the galls formed on the vines grown from cuttings in the experiment just mentioned were more or less spherical in shape and developed below the surface of the ground, often on the lower ends of the cuttings.

In structure these root galls are from the first very spongy and watery. They consist at first entirely of parenchymatous tissue. Later there develops in the interior curled and distorted masses of wood cells and vessels, and older galls occasionally become quite woody, especially where they do not die at the end of the growing season.

The gall develops in every instance, where closely observed, either from an injury to the meristem layer beneath the bark of the cuttings or from a cut surface. An outgrowth of cells first takes place directly from the meristem layer, resembling callus. This develops rapidly into a gall.

DEVELOPMENT OF CANE GALLS.

In the cane galls a similar development takes place, but it is not so rapid. Cane galls usually form along a line of injury, often from a wound made in pruning. Very frequently the bark of the canes of grapevines susceptible to frost, such as the Muscat of Alexandria, is ruptured by freezing in the spring after growth has begun. The bark is usually ruptured in longitudinal lines. From the meristem layer in these wounds there develops directly numerous rough galls which are more or less confluent. This gives rise to the form of disease (Pl. II, fig. 2) known in this country as black-knot (22) and in Europe as broussins (42), rogna (23), and Grind (15). These galls often become more or less woody in structure.

The cane galls have been observed as common, with few exceptions, only in localities where vines are subject to frost injury. Where they have been found on vines, all forms of variation have been noted from the spherical root galls of the roots and crowns of the vines to the confluent cane galls on the shoots, indicating that they are both forms of the same disease.

The cane galls usually dry up in autumn, and may break away from the canes the following season, especially when a further development of galls takes place along their margin.

DEVELOPMENT OF THE DISEASE ON SEEDLINGS.

The seedlings used in the experiments described in this bulletin, unless otherwise designated, were grown from seed sterilized in concentrated sulphuric acid for ten minutes, neutralized with a 10 per cent water solution of potassium hydroxid, and then washed in sterile water. These were planted and grown in soil sterilized in an autoclave at a temperature of 110° C. (230° F.), placed either in pots similarly sterilized or in benches constructed of new pine and cypress lumber, and washed on the surface with a 2 per cent water solution of copper sulphate.

Seedlings of the following varieties of grapes were grown under these conditions: Flame Tokay, Muscat of Alexandria, Mission, Malaga, Black Malvoisie, Concord, Delaware, Catawba, and Niagara. All such seedlings remained free from the disease except where they were wounded and inoculated either with pieces of root galls or with cultures of bacteria. The galls on small seedlings develop at a much more rapid rate than the diameter of the canes or roots of the plants on which they occur; for example, on the root of a vine with a diameter of a quarter of an inch a gall developed in two months with a diameter of an inch (Pl. III, fig. 2).

Cane galls did not develop on any of the plants in the experiments, as all inoculations were made on the vines either at or just below the surface of the soil.

DEVELOPMENT OF THE DISEASE IN VINEYARDS.

In vineyards wherever the disease is found in its worst forms the galls are developed on the roots in great numbers by the end of the third year from the time of planting the vines. Beginning about the fourth year there takes place a development of galls on the canes of some of the diseased plants, but on many vines the disease develops only below the surface of the soil.

THE EFFECT OF CROWN-GALL.

The presence of the disease on grapevines becomes apparent within a short time after they are attacked. Usually the leaves lose their healthy dark-green color and become more or less chlorotic, varying with the intensity of the disease. The growth of the canes becomes slower until they die above the point of attack, due to the cancerous effect of the disease.

The galls have a poor epidermal covering, which is constantly being ruptured during their development. This permits the evaporation of the sap of the vines. In the dry climate of the southwestern United States this loss of sap easily becomes a serious matter and quickly results in the lowering of the vitality of the diseased vines.

In New Mexico, Arizona, and western Texas the vines are usually cut back and grown by the stump system (Pl. IV, fig. 2), in order to cover the vines with soil during the winter as a protection against cold. In spite of the fact that the vines are protected, they are injured in the spring by frost after they are uncovered and severely pruned. The bark is often burst by freezing near the surface of the ground, and this enables the disease to easily gain an entrance on the canes. The vine soon dies above the point of attack (Pl. I). New shoots then develop from the canes or roots below the diseased portion, as shown in this illustration. These shoots are never so vigorous as the original ones and have a tendency to sprawl over the ground, it being a difficult matter to establish a new erect stump or vine (Pl. IV, fig. 1). After the vine dies back a couple of times it is usually worthless, although it may remain alive at the roots. This condition frequently obtains at the end of four to five years under conditions favorable to the disease. In California, Oregon, and Arizona it usually requires a longer period. A large number of vineyards in localities in California where vines suffer little from late frost were found almost free from the disease.

THE SUSCEPTIBILITY AND RESISTANCE OF SPECIES AND VARIETIES OF GRAPES TO CROWN-GALL.

Two factors apparently enter into the problem of the resistance and immunity of grapevines to the disease:

(1) The susceptibility of the species or variety to frosts, etc., in the locality where it is grown. This varies not only with the species but also with the variety grown; for example, the Concord, Catawba, Delaware, and other American varieties are perfectly hardy and usually free from the disease in sections where varieties of *Vitis vinifera* are seriously injured by freezing in winter and late frosts in the spring and become badly diseased.

(2) The variation in the chemical constituents of the sap of different varieties of grapes may enter into the problem of resistance. The sap of the vines of some of the resistant varieties is especially acid to the taste, much more so than that of some of the more susceptible varieties. This acidity may increase the resistance. Unfortunately no chemical determination has been made to fully establish this opinion, and it is offered as a working hypothesis for future investigators.

In the Southern and Western States it was found by observation that varieties of *Vitis vinifera* are less resistant than those of *Vitis labrusca* and *V. aestivalis*, although in Arkansas in the Ozark region two species became slightly diseased, one variety of which, Goethe, a hybrid of *Vitis vinifera* and *V. labrusca*, became badly diseased in a number of instances at the age of from 10 to 12 years. Some varieties of *Vitis aestivalis,* such as Herbemont, appear to be immune to the disease.

Vines of *Vitis cordifolia* and *V. linsecomii* purchased from a nursery were found badly diseased with crown-gall, indicating a susceptibility of these species to the disease.

Vines of varieties of *Vitis rupestris* and *V. vulpina,* so far as observed, are apparently quite resistant, in fact almost immune to the disease; for example, Rupestris St. George and Rupestris Martin.

THE SUSCEPTIBILITY OF VARIETIES OF EUROPEAN GRAPES.

All the data collected from experiments and observation indicate that there is a great range of variation in susceptibility of the varieties of any given species to the disease.

Of the varieties diseased to the greatest extent in any given locality it was observed in general that those most easily injured by late spring frosts are most susceptible to the disease. There are probably some exceptions to this rule, since the disease is able to gain an entrance into the tissues of vines through wounds without the action of frost.

The varieties of *Vitis vinifera* that were found in the experiments most susceptible to the disease were the Mission from California, Muscat of Alexandria, Flame Tokay, Rose of Peru, and Malaga varieties. There are no doubt others not included in the experiments that are equally susceptible.

At Bernalillo, N. Mex., an experimental vineyard for the study of the disease has been conducted since 1903. The vineyard originally contained vines of the Mission variety from California, badly diseased with crown-gall at the age of 4 years (Pl. I). These vines were first treated in various ways in an attempt to control the crown-gall, but without success. The diseased vines were then replaced chiefly with other varieties of *Vitis vinifera* in an effort to obtain resistant vines. A number of the best varieties of commercial wine and table grapes grown on their own roots, purchased in California, were set in the holes from which the diseased Mission grapes had been removed (Pl. IV, fig. 1). This put the new vines to an exact and extreme test, since each vine was planted in infected soil.

The vines of some varieties became badly diseased in two years and were replaced at the end of the second year with more resistant varieties. The following table presents the result of the experiment to July 1, 1909:

TABLE II.—*Percentage of diseased vines of each variety of grapes grown in the experimental vineyard at Bernalillo, N. Mex., in infected soil.*

Variety.	Number of vines grown.	Age.	Proportion of diseased plants resulting.	Growth of plants.
		Years.	*Per cent.*	
Rupestris St. George	300	3	1.0	Very good.
Feher Szagos	500	5	5.0	Do.
Sweetwater	400	3	5.4	Do.
Golden Chasselas	500	3	7.2	Uneven.
Seedless Sultana	300	5	8.1	Good.
Carignane	100	3	9.0	Do.
Grenache	200	3	10.0	Do.
Gros Colman	50	5	11.0	Do.
Mataro	300	3	12.0	Do.
Sauvignon Vert	200	3	13.3	Uneven.
Black Malvoisie	500	3	14.0	Good.
Burger	200	3	17.0	Do.
Lenoir	500	5	18.7	Very good.
Zinfandel	200	5	22.3	Good.
Purple Damascus	100	5	24.0	Uneven.
Thompson Seedless	100	5	24.6	Do.
Riesling	300	5	36.0	Good.
Burgundy	300	3	46.0	Uneven.
Malaga	100	5	52.0	Do.
Rose of Peru	50	3	64.0	Do.
Mission (New Mexico)	1,000	5	75.0	Do.
Flame Tokay	300	3	70.0	Do.
Muscat of Alexandria	650	3	72.5	Do.
Mission (California)	300	5	95.0	Do.

It will be seen from the table that the varieties showing the least disease are headed by the hybrid Rupestris St. George, which shows a resistance of 99 per cent. The vines of this variety that were diseased showed only traces of the crown-gall and no effects whatever. Other promising varieties are Feher Szagos, Sweetwater, Seedless Sultana, Carignane, Grenache, Gros Colman, Mataro, Black Malvoisie, Burger, and Lenoir. The affected vines of these varieties were, as a rule, but slightly diseased, and have shown a good growth.

The most diseased vines, viz, Mission, Muscat of Alexandria, Flame Tokay, Rose of Peru, Malaga, Burgundy, Thompson Seedless, and Purple Damascus, will not prove profitable in infected soil in conditions similar to those at Bernalillo.

The land upon which these vines were grown is a sandy, alluvial deposit of the Rio Grande River, underlain chiefly by sand and gravel. It was examined by Mr. W. W. Mackie, of the Bureau of Soils, October 22, 1906, and samples were taken for a test for alkali. In a report dated November 12, 1906, to the Chief of the Bureau of Soils, Mr. Mackie reported alkali in injurious amount in only three very small areas of the vineyard. This shows that in the greater portion of the vineyard there was not sufficient alkali in the soil to hasten the death of the vines, as is often the case in the arid regions.

The experiment was also not complicated by the presence of phylloxera. The vines were carefully examined each year, but no evidence of their presence was found.

Data collected from nearly a hundred vineyards in six States in the southwestern and western United States yield similar conclusions as to the susceptibility of varieties. The most diseased varieties observed among those commonly grown in vineyards, taken in order from the highest percentage of disease to the lowest, were as follows: Muscat of Alexandria, Malaga, Mission, Flame Tokay, Black Malvoisie, and Zinfandel. Of varieties grown to a much less extent the following, arranged in the same order as before, were also found badly diseased: Black Morocco, Purple Damascus, Early Madelaine, Black Prince, Trousseau, Zabalkanski, Verdel, and Burgundy.

Among the vines commonly grown, those observed to be least affected by the disease, in the order of their immunity, were the following: Seedless Sultana, Sweetwater, Lenoir, Thompson Seedless, Feher Szagos, and Burger.

Of the vines grown to a lesser extent, the least diseased, taken in the same order as before, were Carignane, Gros Colman, Mataro, Black Prince, Black Portugal, and Grenache.

Of stocks for grafting, the Rupestris St. George, Rupestris Martin, and Herbemont appear to be almost immune.

THE RESISTANCE OF VARIETIES OF AMERICAN GRAPES.

The writer conducted no vineyard experiments with varieties of American grapes, but secured data from a number of vineyards in which the disease had appeared. Through the courtesy of Prof. W. G. Vincenheller, director of the Arkansas Agricultural Experiment Station, notes were taken on a vineyard at the station in which there was a large number of varieties of American vines and their hybrids. These vines were about 12 years old, and the disease had been observed in the vineyard for a number of years. The vines were planted on gently sloping land, consisting of an upland clay loam. The diseased vines were chiefly on the upper side of the vineyard, in such a position that the water ran from them to the vines lower down. The cultivation of the plat was made at right angles to the line of drainage, thus tending to spread the germs of disease throughout the plat by cultivation and drainage.

In the table and lists which follow the results of the experiment are given. The names of species of grapes here and elsewhere in this bulletin are in accordance with those used in Bailey's "Cyclopedia of American Horticulture." The data on the ancestry of each variety were furnished by Dr. George C. Husmann, Pomologist in charge of Viticultural Investigations of this Bureau.

TABLE III.—*Percentage of diseased vines of each variety of grapes grown in the experimental vineyard at Fayetteville, Ark., in infected soil.*

Variety.	Variety or hybrid of—	Proportion of diseased plants resulting.
		Per cent.
Mary Ann	*Vitis labrusca*	80
Telegraph	do	40
Perkins	do	20
Dracut Amber	do	20
Duchess	*Vitis labrusca* ×	40
Black Pearl	*Vitis vulpina*	40
Faith	*Vitis vulpina* ×	20
Golden Gem	*Vitis aestivalis* ×	20
Black July	*Vitis aestivalis*	20
Lincoln	do	60
Merrimack	*Vitis labrusca* × *vinifera*	67
Opal	do	50
Goethe	do	40
Centennial	*Vitis aestivalis* × *labrusca*	40
America	*Vitis linsecomii* × *rupestris*	40
Early Market	(*Vitis vulpina* × *labrusca*) × *vulpina*	10

From the table it will be seen that varieties or hybrids of a number of species were susceptible to the disease. In the following list is given the names of those varieties or hybrids which remained free from the disease and are considered resistant, to some extent at least. Since there were, as a rule, not more than five vines of each variety, the small number must be taken into consideration as lessening the chances of infection.

The following varieties or hybrids of American grapes were free from disease:

Of the varieties derived from *Vitis labrusca:* Amanda, Arkansaw, Cambridge, Concord, Cottage, Eaton, Hartford, Illinois City, Ives, Martha, Moores Early, and Wyoming.

Of the varieties derived from *Vitis aestivalis:* Arkansas, Black Herbemont, Onderdonk, Muench, Mrs. Munson, Neva Munson, and Superb.

Of the varieties derived from *Vitis linsecomii:* Great Cluster and Lincy.

Of the hybrids of *Vitis labrusca* × *Vitis vinifera:* Barry, Black Eagle, Governor Ross, Herbert, Highland, Triumph, Campbell's Early, and Conqueror. Of *Vitis labrusca* × *aestivalis:* Gold Coin. Of (*Vitis labrusca* × *vinifera*) × (*aestivalis* × *vinifera*)*:* Brilliant.

Of the hybrids of *Vitis linsecomii* × *aestivalis:* Admirable, Bumper, Delicious, Kemp, Hopkins, Hermann Jaeger, Marguerite, Oriole, Perry, and Vinita. Of *Vitis linsecomii* × *labrusca:* Beacon and Doctor Collier. Of *Vitis linsecomii* × (*labrusca* × *vinifera*)*:* Bailey, Big Extra, Big Hope, Fern Munson, Long John, Newman, R. W. Munson, and W. B. Munson. Of *Vitis linsecomii* × (*aestivalis* × *labrusca*)*:* Laussell. Of *Vitis linsecomii* × (*labrusca* × *vinifera*)*:* Carmen. Of (*Vitis linsecomii* × *rupestris*) × (*labrusca* ×)*:* Rupert.

Of the hybrids of *Vitis champini* × (*labrusca* ×): Chambrill. Of (*Vitis labrusca* × *vinifera*) × *aestivalis:* Lindherbe. Of *Vitis vulpina* × *labrusca:* Ironclad and Taylor. Of *Vitis vulpina* × *aestivalis:* Bell. Of *Vitis vulpina* × *munsoniana:* Elvicand. Of (*Vitis vulpini* × *labrusca*) × *vinifera:* Rommell. Of *Vitis labrusca* × : Moores Diamond, Peter Wylie, and Early Ohio.

Through the courtesy of Dr. Husmann, the writer was permitted to take notes on a large number of vines being tested by him in several localities in California for resistance to phylloxera and alkali. Through observations made in these and other vineyards in California, where vines are being grafted and grown on resistant stocks, it has been noted that where varieties like the Muscat of Alexandria, Mission, and others susceptible to crown-gall are grafted in stocks resistant to phylloxera there is often acquired a resistance to crown-gall.

A number of vineyards were examined in central and southern California in which the vines were grafted on Rupestris St. George and Lenoir and other stocks resistant to phylloxera. These were found to be almost free from crown-gall. Neighboring vineyards of the same age where the vines were grown on their own roots were found to be very considerably or even badly diseased. This gives still greater importance to the need of obtaining resistance by grafting in resistant stocks.

THE CAUSE OF CROWN-GALL.

The earlier investigators of crown-gall mistook the conditions of environment which favor the disease for its cause. The greater number of European observers have assigned the cause of the disease to physical agents, such as late frosts and winter killing. Among those who ascribed the cause of cane galls (Grind, broussin, etc.) primarily to injury received from freezing are Dornfield (15), Köhler (33), Du Breuil (16), Beinling (2), Goethe (28), Viala (55), Frank (21), and Sorauer (48).

Garovaglio and Cattaneo (23) and Dehors (13) thought that the disease might be brought about by injuries received from insects. In addition to the action of frost and injuries by insects, some investigators, according to these writers, have advanced the opinion that a superabundance of the food supply might favor the disease.

Von Thümen (58) found a species of Fusisporium in the galls and ascribed the disease to the action of the fungus, but did not prove its pathogenesis.

Corvo (11) in 1885 noted the presence of bacteria in the tubercles, or galls, on grapevines. Cuboni (12) in 1889 observed bacterial zoogl̄œæ in such galls and compared them with the bacteria in olive knots. Comes (7) in 1891 thought that the disease was caused by *Bacterium gummis* and also the disease known as gummosis. Trevisan [a] named the organism as isolated by Cavara (5) *Bacillus ampelopsorae* n. sp. Cavara (5) claims to have proved the pathogenesis of this organism by inoculation with pure cultures.

Cooke (9) in 1893 described a disease on the roots of grapes much like the crown-gall. He asserted that he found a species of Plasmodiophora in the galls. This in 1903 he designated as *Plasmodiophora vitis* (10). He did not, however, prove the pathogenesis of the organism he found.

Woodworth (60) mentions the finding of a species of *Micrococcus* in grape galls which he grew in a pure culture, but he did not prove the pathogenesis of the organism.

Reddick (41) in 1909 described a fungus *Fusicoccum viticolum*, which he isolated a number of times from the cane galls of grapevines in New York. He ascribed the disease to this fungus.

The writer, in July, 1903, in a study of the disease at Bernalillo, N. Mex., found constantly occurring in the tissues of grape, cane, and root galls and in adjacent diseased tissues a motile bacterial species which was isolated repeatedly and grown in pure cultures in poured agar plates and slant agar tubes in a culture medium consisting of a decoction of celery added to McDougal's culture solution. In agar plates the colonies were round, with a smooth edge, whitish in color, and viscid when drawn out with a needle. No inoculations were made with the organism at the time. These cultures were lost in transit to St. Louis, Mo., where they were sent for further study.

Again, in July, 1904, a number of organisms, including five kinds of bacteria, were isolated from grape root galls. These were grown in pure cultures and inoculated in young Muscat of Alexandria and in Tokay grape seedlings. One of these organisms was in appearance similar to the one found in 1903, and of three Muscat of Alexandria seedlings inoculated with a pure culture of it two became diseased with galls at the point of inoculation. Wounded control plants remained healthy. Although the limited nature of the experiment rendered the results inconclusive, owing to the urgency of the immediately practical aspect of these investigations, this work was not prosecuted further at that time.

In April, 1907, Smith and Townsend (45) of the Bureau of Plant Industry, published an article describing a plant tumor of bacterial origin. They gave conclusive proof of the pathogenesis of the organism *Bacterium tumefaciens*, n. sp., which was isolated from the galls of the Paris daisy, grown in pure cultures, and studied. This organism, when inoculated into healthy plants of tobacco, tomato, potato, sugar beet, hop, and peach produced galls at the point of inoculation.

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[a] Saccardo. Sylloge Fungorum, vol. 8, p. 983.

Wounded control plants of the same species remained free from the disease. This investigation established the relationship of a number of gall diseases and the cause of the crown-gall of the peach, etc. No inoculations were reported at this time on grapevines, but Doctor Smith informs the writer that one successful inoculation was made on the grape, April 3, 1907, and that 18 successful inoculations were obtained in May of that year (all that were inoculated).

During the first week in April, 1907, an organism similar to the one found in 1903 was isolated by the writer from grape root galls and inoculations were made into healthy peach, apple, and apricot seedlings during the second week in April. Of 14 peach seedlings inoculated 9 became diseased with galls at the point of inoculation; of 12 apricot seedlings 6 became similarly diseased; of 5 apple seedlings inoculated none became diseased. The final count was made on November 5, 1907. Wounded control plants of the same kind remained free from disease.

In December, 1908, at a meeting of the Botanical Society of America, Doctor Townsend (51a) reported the results of further experiments with the organism from the Paris daisy. This organism when inoculated into other plants produced galls on the tomato, potato, tobacco, sugar beet, hop, carnation, grape, raspberry, peach, and apple. This proves that galls on the grape may be produced by *Bacterium tumefaciens* and are identical in origin with those on a number of other plants. The galls obtained on the grape by Townsend were both on the canes and roots, and resembled in form the galls on the roots of the grape.

THE COMMUNICABILITY OF CROWN-GALL.

OBSERVATIONS BY OTHER INVESTIGATORS.

Very little has been published on the communicability of crown-gall, except in the line of opinions by observers. These will not be cited.

Lataste (34) communicated the disease to the root of a growing grapevine by binding a piece of living grape gall over a wound.

RESULTS OF EXPERIMENTS.

Experiments with seedlings.—In 1908 the writer (30) published the results of part of a series of experiments on the communicability of the crown-gall from a number of host plants, showing that the disease is communicable from pieces of living tissues of soft crown-galls placed in wounds on the roots of the host plants. These experiments proved the identity of the soft galls of the apple and pear with those of the stone fruits, raspberry, blackberry, and rose. A portion of these experiments was devoted to the communicability of the grape crown-gall. The results of these and other experiments will now be given.

Beginning with 1903 plants were grown each year from seed in the manner described on page 14. Some of these were inoculated at the age of from 3 to 6 months by inserting pieces of living grape root galls into wounds at or below the surface of the soil. Others were wounded without inoculations and set aside as a control. The results of these inoculations were negative in many instances. A summary of the results of these experiments for five years is given in Table IV. Both European and American varieties of grapes were used.

TABLE IV.—*Summary of the results of inoculating seedlings of various kinds of plants with grape crown-gall, 1903–1907.*

Kind of seedlings.	Inoculated plants.			Wounded plants.		
	Number of plants tested.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.	Number of plants tested.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Almond	34	91.2	8.8	62	100.0	0.0
Apple	21	100.0	.0	28	100.0	.0
Apricot	46	100.0	.0	80	100.0	.0
Blackberry	21	95.2	4.8	10	100.0	.0
Chestnut	10	100.0	.0	10	100.0	.0
Cherry	10	80.0	20.0	7	100.0	.0
Grape	262	85.5	14.5	358	99.7	.0
Peach	73	69.9	30.1	71	100.0	.0
Pear	5	100.0	.0	5	100.0	.3
Plum	14	100.0	.0	6	100.0	.0
Raspberry	50	96.0	4.0	125	100.0	.0

The results of the experiments prove the communicability of the grape crown-gall (14.5 per cent) with pieces of galls. They also show that the disease is communicable as follows: To the almond, 8.8 per cent; blackberry, 4.8 per cent; cherry, 20 per cent; peach, 30.1 per cent; and raspberry, 4 per cent. The inoculations on the apple, apricot, chestnut, pear, and plum gave negative results.

Another set of experiments was conducted similarly with grape seedlings, except that the inoculations were made with galls from other host plants. Table V shows the results:

TABLE V.—*Summary of the results of inoculating grape seedlings with galls from other host plants.*

Galls taken from—	Number of grapevines inoculated.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*
Almond	8	100.0	0.0
Apple	81	100.0	.0
Blackberry	38	100.0	.0
Peach	44	93.2	6.8
Pear	13	100.0	.0
Plum	18	100.0	.0
Raspberry	52	92.3	7.7
Rose	57	97.3	2.7
Control	359	99.7	.3

The results from this experiment do not differ radically from the former as regards hosts. They indicate the communicability to the grape from the following hosts: Peach, 6.8 per cent; raspberry, 7.7 per cent; rose, 2.7 per cent. No communicability was shown in the cases of the galls from the almond, apple, blackberry, pear, and plum.

A third set of experiments was conducted in the greenhouse with apparently healthy pear seedlings selected from nursery stock, which were washed clean and inoculated with pieces of crown galls from the roots of grape and other host plants. The results are given in Table VI:

Table VI.—*Summary of the results of inoculating healthy pear seedlings with grape and other galls.*

Galls taken from—	Number of pear trees inoculated.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*
Almond	93	96.8	3.2
Apple	379	99.2	.8
Blackberry	200	91.0	9.0
Cherry	100	83.0	17.0
Grape	387	99.2	.8
Peach	293	78.2	21.8
Pear	83	100.0	.0
Raspberry	197	93.4	6.6
Rose	173	90.2	9.8
Control	196	99.5	.5

The results of the experiment show that the disease is communicable to pear seedlings from other host plants as follows: Almond, 3.2 per cent; apple, 0.8 per cent; blackberry, 9 per cent; cherry, 17 per cent; grape, 0.8 per cent; peach, 21.8 per cent; raspberry, 6.6 per cent; rose, 9.8 per cent. Negative results were obtained again with the pear, also with the apple and grape, on account of the fact that the control plants were diseased in almost the same amount.

The results of these experiments indicate that the crown-gall is communicable to some extent from the grape to the stone fruits and blackberry and raspberry, and vice versa. The degree of communicability to the apple from the grape appears to be almost a negligible quantity.

Experiments with older vines.—The earlier investigators who assumed that freezing, injuries, etc., were the cause of crown-gall erred, but in doing so found the conditions that favor the communicability of the organism causing it.

The cause of the disease can not be ascribed to injuries due to freezing, since the disease is found on plants grown and inoculated in the greenhouse at temperatures far above freezing. Wounds are apparently necessary for the entrance of the organism causing the disease, and freezing produces wounds. Cane galls were observed forming in injuries to vines caused by late frosts at Bernalillo, N. Mex. They were also noted forming in wounds received by cultivation and in those due to pruning. The pruning knife apparently may disseminate the organism.

In a vineyard under the observation of the writer at Bernalillo, a virgin piece of soil was leveled and planted with Mission vines of the New Mexico variety. These were placed on a terrace slightly lower than an older vineyard containing the badly diseased vines of an earlier planting. The new vineyard was planted with healthy vines grown from cuttings taken from healthy vines. The vines grew well and all remained healthy for a year. Then a careless workman who was irrigating by surface irrigation allowed the water to break through a ridge and flow directly from the old vineyard across the center of the new one. The following year the vines in the overflowed portion of the new vineyard became diseased. The fourth year the disease had spread by irrigation to all portions of the vineyard.

In central California it was noted that vineyards that were subirrigated showed little crown-gall, but those of the same varieties in adjacent vineyards that were surface-irrigated showed much of the disease in all portions of the vineyards.

Bees probably communicate the disease as carriers of bacteria found in the galls and the adjacent diseased tissues. In the spring they were observed feeding on the exuding sap after the vines were pruned and then passing from diseased vines to healthy ones.

That the disease can be communicated by means of diseased cuttings has already been shown by the results of the experiment previously described in this bulletin.

THE CURE OF CROWN-GALL.

NEGATIVE RESULTS FROM EXPERIMENTS WITH FUNGICIDES.

As stated on a previous page, the experimental plat at Bernalillo, N. Mex., originally was planted with about 5 acres of grapevines of the Mission (California) variety, and these became badly diseased. All the diseased vines were treated as follows in the spring of 1903 to control the disease: The ground was removed from the base of the vines and all the galls cut away; then the wound was covered with a paste made of copper sulphate and lime.

Some of the vines were probably killed by this treatment, but the disease was not checked, as galls broke forth anew from the vines on other portions of the plants.

The following autumn a portion of the vineyard was again treated as follows: The vineyard was divided into blocks of five rows of 60 vines each. On three adjacent rows of vines about equally diseased the soil was removed around the base of the plants, the galls removed by excision with a sharp knife, and the wound washed with a fungicide. The galls were cut from the vines in an adjacent row, but no chemicals were applied. This row served as a wound control. On a fifth row of vines the galls were undisturbed, as a further control to treatment by excision and by the use of fungicides. This block of five rows made an experiment.

Several such blocks were similarly prepared and three rows treated in each, using the following water solutions of chemicals, a different one in each block: (1) A 2 per cent solution of copper sulphate; (2) a 5 per cent solution of iron sulphate; (3) a 2 per cent solution of formalin. In a fourth block the wound was covered with powdered sulphur. Four more blocks were given the foregoing treatments except that each plant received in addition an application of a fertilizer containing bone phosphates and nitrate of soda.

During the winter which followed many vines in all of the rows died, and of those that lived none certainly recovered. The rows treated showed no improvement over the others. The experiment resulted so badly that the vines were removed and replaced with other varieties in an attempt to secure resistant varieties. Although these experiments failed to accomplish the cure of the diseased vines they can be considered only as indicative of the probable futility of curing the disease by excision of the galls followed by the application of a fungicide. They do not prove the impossibility of a cure by some other method of surgical or chemical treatment.

THE PREVENTION OF CROWN-GALL.

The results of the studies and experiments with the disease indicate the necessity for prevention rather than cure. This can be accomplished either by the use of resistant vines or by grafting nonresistant vines on resistant stocks.

RESISTANT VINES SHOULD BE PLANTED ON THEIR OWN ROOTS.

In the experiment previously described, where 24 of the best varieties were grown in infected soil to test their resistance to attacks by the disease, it was found that a number of varieties were quite resistant to crown-gall, as follows: Rupestris St. George, Feher Szagos, Sweetwater, Golden Chasselas, Seedless Sultana, Carignane, Grenache, Gros Colman, and Mataro. These varieties will succeed well on their own roots. More than a hundred varieties are being tested by Prof. Fabian Garcia, of the New Mexico Agricultural Experiment Station, in an experiment begun in 1904 in cooperation with this Bureau but now being completed by the station. An additional number of resistant varieties will be determined from this experiment.

RESISTANT STOCKS SHOULD BE USED FOR GRAFTING NONRESISTANT VARIETIES.

The Rupestris St. George variety gave the highest degree of resistance to the disease and grew vigorously. This variety is of no value except as a stock for the purpose of bench grafting. Its resistance to the disease being very high makes it a valuable vine for this purpose. Its resistance to the phylloxera makes it doubly valuable, since sooner or later this pest will be likely to appear in every vineyard region where European varieties of grapes are grown.

The Lenoir variety, used as a stock for grafting, is also valuable as a wine grape. Although quite a number of vines of this variety became slightly diseased in the experiments, none were seriously affected, and it is recommended as a good vine for the Southwest wherever the crown-gall has appeared, either when grown for its fruit or as a stock for ingrafting more susceptible varieties. It is not within the province of this bulletin to enter fully into the discussion of all the varieties of vines resistant to the phylloxera, most of which will very probably be found resistant to the crown-gall.

In localities where the ravages of the disease are marked, it is not advisable to plant the Mission variety, especially the Mission from California, the Muscat of Alexandria, Flame Tokay, Rose of Peru, Malaga, Burgundy, or Riesling varieties unless grafted upon resistant stocks.

OTHER MEANS OF PREVENTION.

When vines are grown from cuttings, care should be taken to secure cuttings from vineyards free from the disease. Such cuttings should be grown in soil where vines have not been grown for five or more years.

In planting vines or cuttings in the arid regions it is best to plant them deeply, so that not more than one bud or eye will remain above the soil. This will protect them both from freezing and from the burning sun, both of which are injurious to the young vines and lower their vitality even though an entrance of the disease may not take place.

In case a vineyard or locality is free from crown-gall it is best to be exceedingly careful where vines are purchased for planting. That the nursery is free from the disease should be ascertained before purchasing varieties of European grapes. It is better, where possible, to propagate vines by bench-grafting on healthy stocks grown at home from cuttings selected from healthy vines.

SUMMARY AND RECOMMENDATIONS.

The disease of grapes in this country designated as black-knot, crown-knot, root-knot, crown-gall, and as root tumors has been known for many years. In Europe it has been known for a longer period as "Grind," "Kropf," "broussins," "rogna," "tuberculosi," etc.

Two forms of the disease occur commonly on varieties of *Vitis vinifera* in the southwestern and western United States. One form occurring as rough, often hard, excrescences on the canes of grapevines is designated as cane galls in this bulletin and is also known as "black-knot," "Grind," "broussins," "rogna," etc. (Pl. II, fig. 2.) The other form, occurring at or below the surface of the ground on the crowns and roots of the vines in the form of soft galls, is designated as root galls in this paper, but is also known as "tumors," "Kropf," "rogna," and "tuberculosi." (Pl. III, fig. 1.)

The crown-gall, or a similar disease, is widely disseminated in many parts of the world, especially where varieties of *Vitis vinifera* are grown.

The entrance of the disease in vines is favored by injuries, such as those due to freezing and late frosts, to pruning, etc. The effect of the disease is very destructive, often killing or stunting nearly all the vines in a vineyard in a few years, resulting in a heavy loss in many localities, especially in the western United States.

The galls usually develop annually, rotting away at the end of the growing season, the rot killing the adjacent tissues and cutting off the circulation of the vine, having much the effect of a cancer.

A great variation in the resistance to the disease is shown by many varieties of European and American grapes. Of European grapes the Muscat of Alexandria and the Mission of California were found to be the most susceptible varieties. No species of *Vitis vinifera* was found to be entirely immune. Some hybrids with American varieties possess a high degree of resistance. Among these are the Rupestris St. George and other similar varieties. The Lenoir possesses a high degree of resistance and is in many ways desirable as a grafting stock.

In New Mexico the varieties found most resistant were Feher Szagos, Sweetwater, Seedless Sultana, Carignane, Grenache, Gros Colman, Mataro, Black Malvoisie, Burger, and Lenoir. These vines are more or less resistant on their own roots and are recommended for planting in infected vineyards. A higher resistance to the disease can be obtained by grafting these or other desirable varieties on such stocks as the Rupestris St. George and the Lenoir, which are also resistant to phylloxera.

The disease is communicated in a number of ways: (1) By the water of irrigation; (2) by cuttings from diseased plants; (3) probably by the pruning knife; and (4) by insects.

As a protection against frost injuries, cuttings or young vines should be planted deeply in the soil, especially in arid regions, allowing only one bud to project above the surface of the ground.

Cuttings and young vines should be secured from healthy surroundings. It is better to use vines grown under one's personal supervision than to purchase from a vineyard or nursery known to be infected with the disease.

Grapevines should be pruned in the spring either before or just after the period of sap flow, the time varying with the locality. They should be protected in winter from freezing where necessary, and the protective covering should not be removed until the danger of injury is passed, because the wounds produced by late frosts afford a means of entrance to the organisms causing the disease.

Finally, in a new vineyard resistant vines should be planted if possible. If it is necessary to grow nonresistant vines they should be grafted on stocks that are resistant. All diseased vines should be burned as soon as they are discovered and replaced with healthy resistant vines.

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PLATES.

DESCRIPTION OF PLATES.

Plate I. *Frontispiece.* A 4-year-old Mission grapevine from the experimental vineyard at Bernalillo, N. Mex., badly diseased both above and below the surface of the ground. The young offshoot is the result of an attempt on the part of the vine to renew itself.

Plate II. Fig. 1.—A 4-year-old Muscat of Alexandria grapevine from the experimental vineyard at Bernalillo, N. Mex., badly diseased with confluent root galls. Fig. 2.—Another Muscat of Alexandria grapevine from the same lot as that shown in Figure 1 diseased with confluent root galls below and cane galls above.

Plate III. Fig. 1.—Root galls on a badly diseased Flame Tokay grapevine from the same vineyard as those shown in Plate II. (One-third natural size.) Fig. 2.—A Muscat grapevine diseased with a globose gall, resulting from an inoculation.

Plate IV. Fig. 1.—View of a portion of the experimental vineyard at Bernalillo, N. Mex., before the diseased Mission vines were replaced with other varieties. Fig. 2.—A view of a portion of the experimental vineyard at Bernalillo, N. Mex., after it had been planted with resistant vines.

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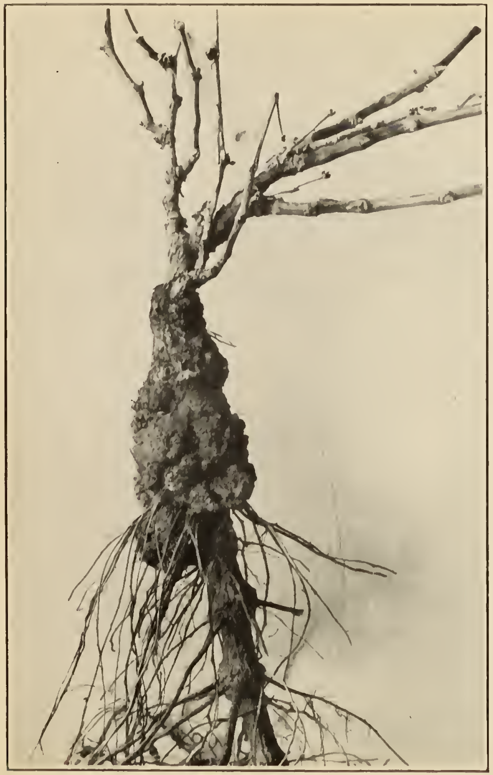

FIG. 1.—A MUSCAT OF ALEXANDRIA GRAPEVINE DISEASED WITH CONFLUENT ROOT GALLS.

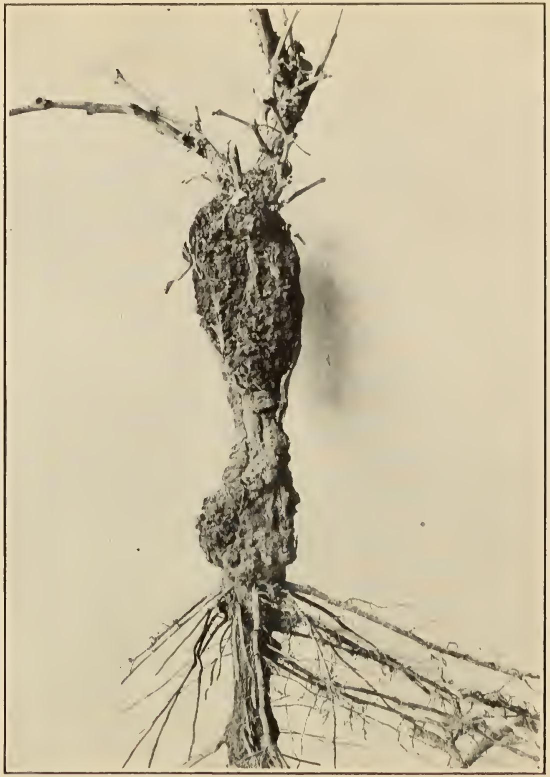

FIG. 2.—A MUSCAT OF ALEXANDRIA GRAPEVINE DISEASED WITH CONFLUENT GALLS ON BOTH THE CANE AND ROOT.

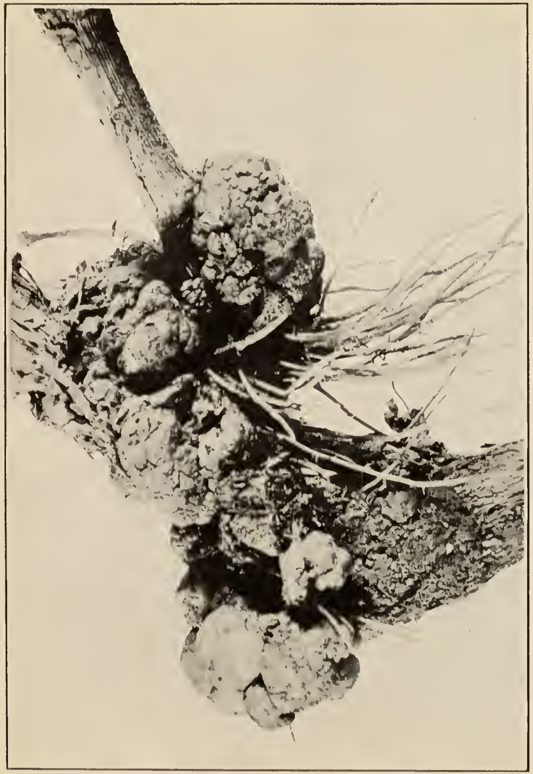

FIG. 1.—A FLAME TOKAY GRAPEVINE DISEASED WITH GLOBOSE ROOT GALLS.

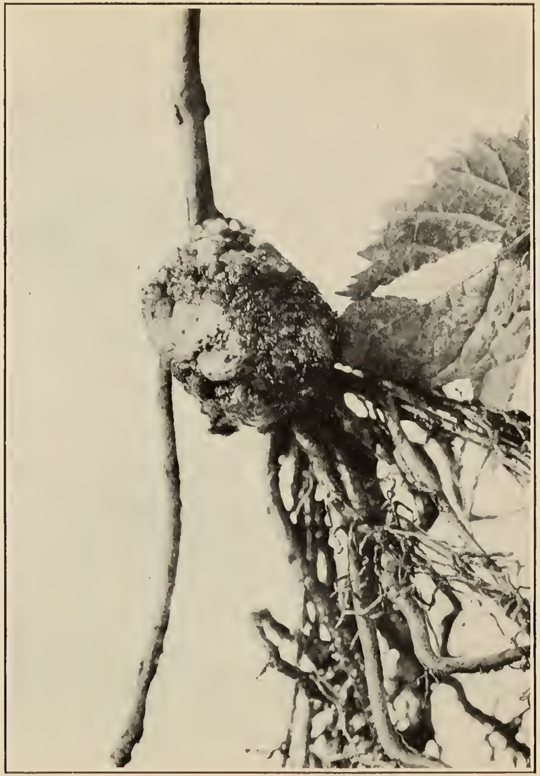

FIG. 2—A GLOBOSE ROOT GALL ON A MUSCAT OF ALEXANDRIA GRAPE SEEDLING.

PLATE IV.

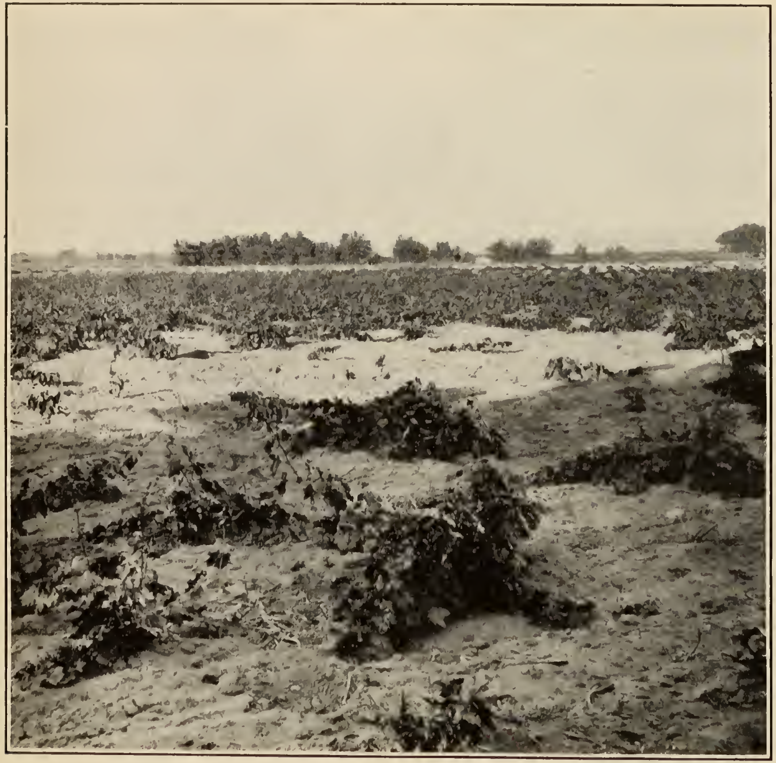

FIG. 1.—A PORTION OF THE EXPERIMENTAL VINEYARD AT BERNALILLO, N. MEX., SHOWING DISEASED MISSION GRAPEVINES.

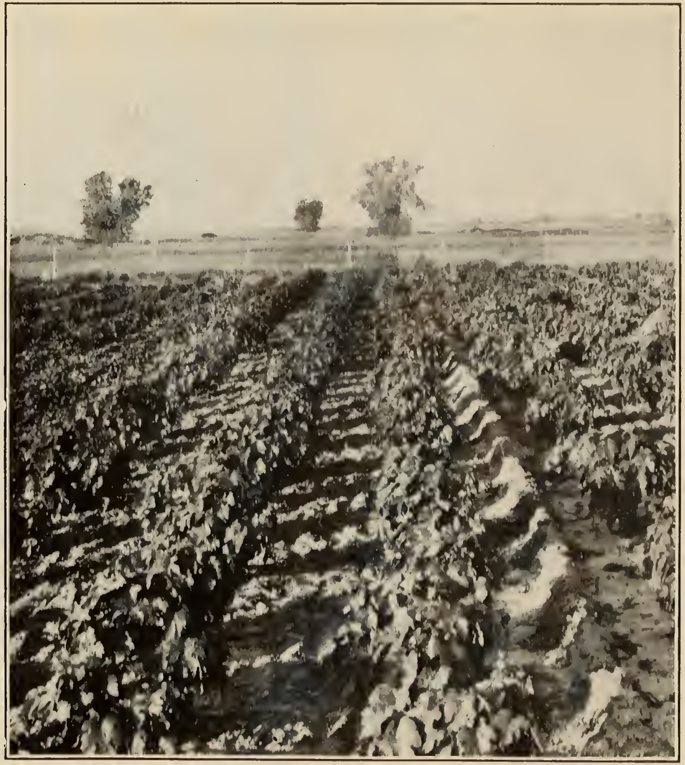

FIG. 2.—A PORTION OF THE EXPERIMENTAL VINEYARD AT BERNALILLO, N. MEX., AFTER IT HAD BEEN PLANTED WITH RESISTANT GRAPEVINES.

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